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The transmittance was reduced as compared with the small thickness of the Au film conceivably because the transmittance of the IDIXO film itself was reduced due to the presence of Au.

REMARKS:

1) This Voluntary Amendment is a Supplement to the Response that was filed on September 6, 2001. The prior Response was fully responsive to all issues raised in the Office Action of June 6, 2001, so that there is no period for response running in connection with the present Voluntary Amendment, and no Term Extension is required.

2) The Examiner's attention is directed to the enclosed Letter to the Official Draftsperson, accompanied by seven sheets of revised drawings showing proposed corrections.

To better comply with the Rules, the sub-figures (a), (b), (c) and (d) of original Fig. 1 have been separately labeled as Fig. 1A, Fig. 1B, Fig. 1C and Fig. 1D.

To more clearly show the three separate curves or lines of data points in original Fig. 6, it is proposed to divide Fig.6 into three separate Figures, namely Fig. 6A, Fig. 6B, and Fig. 6C.

To more clearly show the three separate curves or lines of data points in original Fig. 7, it is proposed to divide Fig. 7

into three separate Figures, namely Fig. 7A, Fig. 7B, and Fig. 7C.

Since these corrections merely involve relabeling Figures and dividing two original Figures respectively into distinct sub-figures, no new matter is involved.

The specification has been amended to conform to the revised drawings.

Approval of the proposed revisions is respectfully requested.

Proper formal drawings incorporating the present revisions will be filed once the application has been allowed.

3) The specification has been amended to conform to the presently submitted drawing revisions. Since the amendments merely involve the relabeling of certain Figures, and the division of some Figures into separate sub-views, no new matter is involved. It is respectfully submitted that the written description and the drawings can now be more easily and readily understood in connection with each other. A marked-up version of the affected portions of the specification is enclosed, to show the subject matter being added to and deleted from the specification of record. Entry of the amendments is respectfully requested.

4) In a Telephone Interview on September 26, 2001, the Examiner said that he would consider this Voluntary Amendment together with the Response of September 6, 2001, when next examining the application. The Examiner's consideration is appreciated.

5) Favorable reconsideration and allowance of the application, including all present claims 1 and 4 to 7, are respectfully requested, in view of the Response dated September 6, 2001 together with the present Voluntary Amendment.

Respectfully submitted,

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WFF:ar/3905
Encls.:postcard, marked-up version of spec. pgs. 8, 9, 14, and 17;
Letter to Draftsman and a red-marked file copy of drawing Figs. 1, 6, 7

CERTIFICATE OF MAILING:

I hereby certify that this correspondence with all enclosures is being mailed on the date indicated below as first-class mail, postage pre-paid, in an envelope addressed to: Commissioner for Patents, Box Response - No Fee, Washington, D. C. 20231.

Walter F. Fasse 10/3/01
Walter F. Fasse - October 3, 2001

Docket # 3905
S/N: 09/519,408
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"Marked-up Version"

Figs. 1A 1B, 1C and 1D illustrate

[Fig. 1 includes diagrams (a) to (d) for illustrating] the structure of a semiconductor light-emitting device according to a first embodiment of the present invention and certain comparative features thereof;

Fig. 2 is a sectional view of a specific example of the semiconductor light-emitting device according to the first embodiment;

Fig. 3 is a conceptual diagram for illustrating improvement of optical output in a semiconductor light-emitting diode according to a second embodiment of the present invention;

Fig. 4 is a conceptual diagram of a laser ablation film forming apparatus;

Fig. 5 illustrates the relation between resistivity of an IDIXO film having a thickness of 120 nm and oxygen pressure;

Figs. 6A, 6B and 6C illustrate the [Fig. 6 illustrates] oxygen pressure dependency of transmittance of the IDIXO film having a thickness of 120 nm by showing the transmittance characteristic at three different pressures;

Figs. 7A, 7B and 7C illustrate the [Fig. 7 illustrates wavelength] dependency of transmittance of IDIXO (120 nm)/Au with respect to the film thickness of the Au film by showing the transmittance characteristic at three different Au film thicknesses;

Fig. 8 is a sectional view of a compound semiconductor light-emitting device obtained according to the present invention;

Figs. 9A and 9B are sectional views of a conventional light-emitting device;

Fig. 10 is a sectional view showing the structure of a conventional LED; and

Fig. 11 is a sectional view of a conventional LED having a current diffusion electrode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

In a first embodiment of the present invention, a transparent conductor film having low resistance and high transmittance is employed in place of a conventional Au film. Referring to [(a) of Fig. 1] Fig. 1A, the transparent conductor film is applied as a p-type electrode in the first embodiment of the present invention in particular. comparative Fig. 1C

Referring to [(c) of Fig. 1], a transparent conductor film 30 generally consists of an n-type semiconductor, and inevitably forms a junction when

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directly formed on a p-type semiconductor layer 24. Referring to (b) of Fig. 1, transmittance as well as luminous efficiency are reduced when an Au a relatively thick film 26 is formed on a p-type semiconductor layer 24.

Referring to (d) of Fig. 1 Fig. 1D, an extremely thin Au thin film 10a is formed on a p-type semiconductor layer 24, and a transparent conductor film 10b is thereafter stacked thereon according to the present invention. The Au thin film 10a has a sufficiently small thickness of 1 to 3 nm, so that the transmittance is not remarkably reduced. The transparent conductor film 10b having high transmittance can be formed in with a relatively large thickness. Consequently, a current effectively spreads over an electrode through the transparent conductor film 10b.

Fig. 2 is a sectional view of a ZnSe compound semiconductor light-emitting device to which the present invention is applied. An n-type ZnSe buffer layer 2 of 1 μm in thickness, an n-type ZnMgSSe clad layer 3 of 1 μm in thickness, a ZnSe/ZnCdSe multiple quantum well active layer 4, a p-type ZnMgSSe clad layer 5 of 1 μm in thickness, a p-type ZnSe layer 6 of 0.2 μm in thickness and a p-type contact layer 7 consisting of a multilayer superlattice structure of ZnTe and ZnSe are successively provided on a conductive ZnSe single-crystalline substrate 1 having an n-type electrode 12 on the back surface. A p-type ZnTe layer 8 of 60 nm in thickness is provided on the uppermost surface. An upper electrode 10 having a multilayer structure of an Au thin film 10a of 1 to 3 nm in thickness and a transparent conductor film 10b formed thereon is formed on such an epi-structure.

<u>Second Embodiment</u>

A second embodiment of the present invention relates to a technique of extracting light, which is unextractable due to total reflection, by (e.g., irregularly) controlling the surface shape of a transparent conductor film. Thus, optical output can be improved. Fig. 3 illustrates the concept of this embodiment.

The following equation holds according to the Snell's law:

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

Assuming that $n_1 = 3.5$ (semiconductor) and $n_2 = 1$ (air), an angle θ_1

120 nm.

Fig. 5 shows the relation between resistivity and oxygen pressure. The resistivity remarkably varied with the oxygen pressure, and a characteristic having a dip was obtained at 3×10^{-3} Torr. This agrees with the hitherto report that the resistance of a transparent conductor film has an optimum value depending on the amount of oxygen. It is extremely difficult to obtain the lowest value of 6.5×10^{-5} Ωcm by conventional sputtering. Thus, the resistivity is lower by about one figure as compared with sputtering, and hence the necessary thickness can be reduced to 1/10, the transmittance can be increased and a high-quality transparent conductor film can be prepared at a low cost. The surface of the film prepared under these conditions was extremely smooth with roughness of about 0.5 nm. This value is about 1/10 that of a film prepared by sputtering.

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Figs. 6A, 6B, and 6C show

~~Fig. 6 shows~~ results of evaluation of the oxygen pressure dependency of transmittance of IDIXO films on substrates of MgO, respectively for three different film forming oxygen pressures. An absorption edge of about 300 nm is recognized. The sample for measuring transmittance was formed by a substrate of MgO having an absorption edge of about 200 nm, and it is understood that absorption of 300 nm results from the IDIXO film. The transmittance of the MgO substrate measured at a wavelength of 500 nm was 84 %, and the relation between the film forming oxygen pressure and the transmittance of the IDIXO film (120 nm) can be calculated as shown in Table 3.

Table 3

Film Forming Oxygen Pressure	IDIXO Transmittance
0.3 Torr	99%
~~3×10^{-3} Torr~~ 3×10^{-2} Torr	87%
3×10^{-3} Torr	92%

At the film forming pressure of 0.3 Torr, the resistivity is extremely increased although high transmittance is obtained. At the film forming

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formed as a p electrode of a ZnSe LED. In order to avoid this, an IDIXO/Au structure obtained by forming an Au film before forming an IDIXO film was studied. Table 6 shows results in relation to resistivity.

Table 6

Thickness of Au Film	Resistivity
3nm	$1.2\times10^{-4}\Omega cm$
10nm	$6.0\times10^{-5}\Omega cm$

As compared with a smooth glass substrate, slightly higher resistivity was obtained when the thickness of the Au film was 3 nm, and substantially identical resistivity was obtained when the thickness was 10 nm. When the thickness of the Au film was 3 nm, the resistivity was increased conceivably because no continuous film of IDIXO was grown in an initial stage due to the presence of Au (not contributing to electrical conduction) grown in the form of an island. When the thickness of the Au film was 10 nm, Au formed a continuous film to compensate for reduction of electrical conduction of IDIXO. Figs. 7A, 7B and 7C show

~~Fig. 7 shows~~ transmittance in IDIXO/Au electrode structures having three different film thicknesses of the Au film, respectively. Reduction of transmittance resulting from the presence of Au is recognized. At a wavelength of 500 nm, the transmittance of the sample of IDIXO (120 nm)/Au (3 nm) is about 80 %. The transmittance was reduced as compared with the small thickness of the Au film conceivably because the transmittance of the IDIXO film itself was reduced due to the presence of Au.

Fourth Embodiment

Fig. 8 is a sectional view of a compound semiconductor light-emitting device manufactured with application of the method of manufacturing a transparent conductor film according to the third embodiment of the present invention. Referring to Fig. 8, an n electrode 52 is provided on the back surface of an n-type semiconductor layer 51. An active layer 53 is provided on the n-type semiconductor layer 51. A p-type semiconductor layer 54 is provided on the active layer 53. A contact layer 55 is provided